MISSION STATEMENT

Midrex Direct Reduction Corporation will lead in the ironmaking technology industry by supplying superior quality services that provide good value for our clients. We will meet or exceed performance expectations, execute projects on time, enhance existing product lines, and develop or acquire new technologies. Our employees are the key to our success, and we are committed to encouraging them to grow professionally and personally.
Corus Tuscaloosa Steel Company operates a mini-mill in Tuscaloosa, Alabama. The facility includes a 23 foot diameter, 116 MVA, 150 NT tap weight twin shell DC electric arc furnace. The furnace is equipped with a system to continuously charge DRI produced at Corus Mobile DRI in Mobile, Alabama, or other sources. The present melting practice is to charge a total of 45-50 percent DRI, 10 percent in the scrap bucket and the remainder continuously fed. This leads to an energy consumption and tap to tap time of 398 kWh/ton liquid steel and 58 minutes, respectively (compared to 100 percent scrap figures of 421 kWh/ton and 61 minutes).

Given the growth in DRI production and use, melting practices are being developed and refined. Whereas to date AC furnace experience predominates, DRI use in DC furnaces is expanding rapidly. Initially, a comparison of AC versus DC EAFs led to a lengthy list of differences. On closer inspection, the differences were not AC/DC related but rather due to shop specific practices. Ultimately, the major differences are method of power transfer and control, arc length and foamy slag practice.

The mechanisms for power transfer to the charge are quite different. In the AC furnace, the arc is struck between the electrodes (normally three in number) and the charge. The current passes through the charge and returns via a second arc to the electrodes. Initially, if the charge is cold and largely scrap, there is an inherent arc length variability and accompanying noise which lessens as the charge compacts, arc length stabilizes and melting begins. The passage of the current through the charge creates resistance heating and once a molten pool of steel is formed, the current path is from the electrodes to the bath.

In the case of a DC furnace, the electrode (single or dual) acts as the cathode and the return electrode, the anode, is a “bottom electrode” of one of the following designs: a conductive bottom, billet, metal fin or metal pin type. Power flows from the electrode(s) through the cold scrap, to the cathode. As with AC EAFs, heating is resistance in nature.

The control scheme is quite different, being current controlled in the AC furnace and voltage controlled in the DC furnace. The arc length is 12 to 20 inches in an AC furnace and 36 to 48 inches in the DC furnace though the maximum power input is the same in each case.

For batch charging of DRI, I know of no significant differences between AC and DC operations. For continuous charging, there are some important considerations. AC furnaces have a built-in path to the molten bath. With a DC furnace, however, it is necessary to create a path to the molten bath by ensuring there is a good foamy slag operation to insulate and direct the arc. While the foamy slag practice is critical for good operations in either case, slag height is more critical for DC furnaces due to the longer arc length cited above. The allowable DRI feed rate is the same for both, being between 27 and 45 kg/min/MW.

In general, DRI can be successfully melted in either an AC or DC furnace, and both types of practices are in use throughout the world. The DRI can be charged either in the scrap bucket, continuously, or by a combination of the two. The most important factor for either EAF type is the creation of a good foamy slag.
Batch Charging of DRI at Gallatin Steel

By Jim Mullen
Steelmaking Metallurgist
Gallatin Steel

INTRODUCTION
Gallatin Steel Company, a joint venture of Dofasco and CoSteel, began operations in 1995. The mini-mill includes a twin shell NKK-SE/MAN GHH 200 NT capacity (190 NT tap weight) DC electric arc furnace, an NKK-SE ladle furnace station and a single strand thin-slab caster producing hot rolled commercial and drawing quality carbon and high strength low alloy steel coils.

Gallatin's charge mix consists of home scrap, purchased scrap (including shredded, busheling, HMS and plate and structural), pig iron and DRI. DRI is received by barge, offloaded, and either stored in the three barge capacity buildings at the dock or on the ground. It is then trucked to a location in the scrap bay where 500 to 600 NT of DRI can be staged for charging into buckets.

CHARGING PRACTICE
The DRI is charged into 200 NT scrap buckets using a practice developed and refined over several years. Of the different layering methods tried, the preferred method is charging the DRI low in the bucket, as shown in Figure 1. This ensures the majority of the DRI falls directly into the liquid heel, minimizing DRI blockage of the slag door, which can cause problems for the oxygen lances. Even using this method, some skulls still form on the furnace sidewalls, creating problems for the burners, but less so than when the DRI is layered throughout the charge.

Since 1998, Gallatin Steel has increased the DRI charged from 11 percent to 17 percent. During this time, electrical consumption increased slightly (389 kWh/NT to 398 kWh/NT) and power-on time decreased (58.6 minutes to 52.8 minutes), though not due to DRI. Initially, burners were used to decrease the electrical consumption but skull formation hampered their efficiency and led to their subsequent removal. The power-on time decrease was due to the improved foamy slag practice. Figure 2 shows the evolution of electricity consumption from 1998 throughout 1999.

FOAMY SLAG PRACTICE
Gallatin has improved its foamy slag practice significantly. Prior to 1999, the practice did not produce sufficient foaming to bury the arc, which is critical for DC furnaces, and the furnaces had to be operated at a lower power input to avoid damage. Beginning in early 1999, an improved practice was implemented, which buries the arc and allows higher power input operating levels. The changes involved a switch from dolomitic lime to dead-burnt magnesite with an accompanying “V-ratio” \[\frac{CaO}{SiO_2+Al_2O_3}\] decrease from 2.2 to 1.6-1.8.

CONCLUSIONS
Gallatin Steel has operated for four years with 10-20 percent DRI in the charge.

The benefits of 17.5 percent DRI use include: lower residuals and nitrogen contents (critical for product mix), lower price than low residual scrap and use of one bucket charge (higher productivity).

Negatives of DRI use are: sidewall skull formation (causes problems for sidewall burners) and, at 20 percent bucket charged DRI, build up and late cave-ins cause delayed reactions in the bath (continuous charging is being explored).

Figure 1  One Bucket Charge Layering Practice

Figure 2  kWh/scrap ton compared to DRI/HBI usage
INTRODUCTION

It is a generally accepted fact that the blast furnace will continue to be the dominant means of hot metal production serving the steelmaking industry for now and many years to come. Nevertheless, there are both economic and process related limitations to the blast furnace route that challenge its dominance and prohibit future adoption for greenfield applications.

The wastes that steelmaking operations have been producing and landfills for years are now a potential asset in raw material cost savings. These materials can be recycled to make DRI for feed to blast furnaces, melters or even used to produce blast furnace grade hot metal for incorporation in downstream steelmaking processes (e.g., EAF or BOP). Over the past year this technology has progressed from a developmental stage to a commercial operating stage. [Ed. Note: See “From Dust to DRI” for more about the development and commercial operations.]

FASTMET® Plants that produce hot DRI are in commercial operation and several FASTMELT® Plants are in the proposal stage. Detailed design work for the FASTMELT Facility has been completed and pilot work at the Midrex Technical Center has shown the process to be viable. The FASTMELT Process is attractive from the environmental perspective as it can be viewed as combining some of the best features of gas-based pre-reduction with electric melting.

STEELMAKING WASTES & ASSOCIATED PROBLEMS

Many steel mills today are concerned about the handling of wastes. Some of these problems that are compounding yearly are:

- **Disposal of iron-bearing wastes** – Non-hazardous wastes from integrated mills can cost $20/net ton (NT) or more to send to a landfill. Electric furnace baghouse dust, which is listed as a hazardous material (KO61) by the EPA, can cost $150/NT or more to be thermally processed or stabilized.
- **Closure of on-site landfills** – Steel mills worldwide have stockpiled wastes on site for years, some even decades; however, many of these on-site landfills are filling up and coming under increased scrutiny by environmental authorities.
- **Recovery of valuable iron units** – Integrated mills pay $40-45/gross ton (GT) for iron oxide pellets. With a typical iron content of 65 percent, this translates to a metallic iron cost of $60-70/GT. The mill is literally throwing money away if the pellet fines are not recycled. In the case where mini or integrated mills are using DRI as feed, the economic effect of not recycling DRI fines can be threefold that of oxide pellets.
- **Controlling steelmaking raw material costs** – One effective way to do this is by processing waste materials and thereby eliminating the associated landfill fee.
- **Conservation of capital** – An on-site waste processing plant that is built, owned and operated by a third party allows steelmakers to conserve capital funds and avoid the responsibility of another hot end operation.
- **Environmental problems of coke ovens and sinter plants** – Stricter EPA regulations on integrated mill emissions, especially from coke ovens, are a major problem. Many companies would shut down sinter plants and coke ovens if there was a viable alternative.

Over the past 10 years, Midrex and Kobe Steel have developed the processes to enable the FASTMET and FASTMELT steelmaker to deal with steel mill waste problems. The FASTMET Process converts steel mill wastes, with or without the addition of iron ore fines, into metallized iron in a rotary hearth furnace (RHF) using carbon as the reductant. The product is cold DRI, hot DRI or HBI. The FASTMELT Process uses the FASTMET RHF to produce DRI, which is then fed to an electric melter known as an Electric Ironmaking Furnace (EIF®), developed by EMC International, a sister company to Midrex. The EIF produces a high quality liquid iron known as FASTIRON®.

[Ed. Note: For more information on the history of FASTMET and FASTMELT see Direct From Midrex 4th Quarter 1998 which is downloadable from www.midrex.com]

RAW MATERIALS SUITABLE FOR PROCESSING

There are three categories of raw materials for the FASTMET and FASTMELT process: iron oxides (i.e., virgin materials or iron bearing materials), reductants (i.e., carbon source) and a binder. An extensive group of raw material combinations (i.e., iron bearing waste materials and different reductants) have been evaluated in laboratory scale testing, pilot plant work and/or testwork at Kobe Steel’s Demonstration Plant in Kakogawa, Japan. A partial list of raw materials is given below:

- Blast furnace filter cake
- BOF filter cake
- Mill scale
- EAF baghouse dust
- Pellet fines
- Iron ore concentrates
- Blast furnace dust and sludge
- Coke breeze
- Low/medium/high volatile coals
- Pet coke

If blast furnace dust or sludge is used, there may be sufficient carbon in the feed to accomplish reduction without additional reductant.
THE EAF WASTE TREATMENT OPTION

FASTMET leaves the mini-mill another option for handling steel waste over the current high treatment costs. A FASTMET Plant located at the steelmaking site can process the waste and make two primary products, DRI for feed back to the EAF and ZnO for sale to zinc processors. What was a liability now becomes an asset. The high cost of disposal is eliminated and an inexpensive supply of iron units becomes available. To summarize the benefits:

- Very low fines generation in the process results in high zinc content and very low iron content of the secondary dust
- High metallization and high zinc removal make reduced iron product recyclable to the EAF
- No waste is generated for disposal
- High temperature treatment decomposes dioxins
- Zinc dust can be treated economically and becomes a product, not a waste

Table I shows the results of a laboratory simulation test of typical EAF dust using FASTMET. The case (EAF dust + coal) represents EAF dust processing using coal as reducing agent.

ENVIROMENTAL BENEFITS

The FASTMET and FASTMELT processes are environmentally attractive, with slag and baghouse dust the only solid wastes generated. The slag is similar to blast furnace slag and can be handled in the same way. The baghouse dust can be sold for the ZnO content. Any remaining solid wastes are recycled to the process.

There are no process water discharges and air emissions are controlled within EPA limits using the necessary control equipment. Furthermore, overall process carbon dioxide emissions for production of steel are minimized by virtue of the unique combination of technologies: the RHF and EIF.

In FASTMELT Plants with more sophisticated options, hot flue gas energy from the RHF can be effectively converted into electricity by means of cogeneration followed by process air recuperation. Cogeneration can easily accommodate 40-45% of the total FASTMELT Process electric energy requirement and provide adequate process air recuperation without significantly impacting coal requirements. More electric power can be produced with additional fuel burned with the RHF flue gas. Some commercial studies have cogeneration as a source for all electrical energy requirements for the FASTMELT Plant, as well as additional power to sell back to the local power grid.

Cogeneration needs to be carefully evaluated given capital cost, fuel cost, steam generation capacity, availability and cost for electrical power from the local utility as well as price for power buyback.

ADVANTAGES OF THE EIF

The EIF was designed to satisfy the following objectives: effective melting of FASTMET DRI, removal of gangue, reduction of residual FeO to Fe, desulfurization and continuous operation. A cross-sectional illustration of the EIF is shown in Figure 1.

For producing hot metal, the use of the EIF in the FASTMELT Process provides a number of advantages versus the submerged arc furnace (SAF).

Table I  EAF Dust Treatment (Weight %)

<table>
<thead>
<tr>
<th>EAF dust + Coal</th>
<th>Total Fe</th>
<th>Met. Fe</th>
<th>C</th>
<th>ZnO</th>
<th>PbO</th>
</tr>
</thead>
<tbody>
<tr>
<td>EAF dust</td>
<td>32.23</td>
<td>0.02</td>
<td>1.70</td>
<td>24.20</td>
<td>4.10</td>
</tr>
<tr>
<td>Coal</td>
<td>0.45</td>
<td>0.00</td>
<td>74.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>DRI</td>
<td>58.09</td>
<td>52.28</td>
<td>2.02</td>
<td>2.18</td>
<td>0.00</td>
</tr>
<tr>
<td>By-product</td>
<td>0.05</td>
<td>0.04</td>
<td>0.00</td>
<td>74.33</td>
<td>13.26</td>
</tr>
</tbody>
</table>

Table II  Comparison of SAF and EIF Furnaces

<table>
<thead>
<tr>
<th>SAF</th>
<th>EIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Source</td>
<td>Slag Resistance</td>
</tr>
<tr>
<td></td>
<td>Low Met. DRI</td>
</tr>
<tr>
<td></td>
<td>Lime</td>
</tr>
<tr>
<td></td>
<td>Iron Oxides</td>
</tr>
<tr>
<td></td>
<td>Carburizers</td>
</tr>
<tr>
<td></td>
<td>Choke Fed</td>
</tr>
<tr>
<td>Metallization of DRI</td>
<td>60 to 80%</td>
</tr>
<tr>
<td>Heat Input*</td>
<td>800 kWh/t</td>
</tr>
<tr>
<td>Hot Metal Composition</td>
<td>C: 3.5 – 3.8%</td>
</tr>
<tr>
<td></td>
<td>Si: 0.5 – 1.5%</td>
</tr>
<tr>
<td></td>
<td>S: 0.05%</td>
</tr>
<tr>
<td></td>
<td>RPF: 85 to 95%</td>
</tr>
<tr>
<td></td>
<td>550 kWh/t</td>
</tr>
<tr>
<td></td>
<td>C: 4.2 – 4.8%</td>
</tr>
<tr>
<td></td>
<td>Si: 0.3 – 0.7%</td>
</tr>
<tr>
<td></td>
<td>S: 0.03%</td>
</tr>
</tbody>
</table>

Based on theoretical calculations
DRI (80-90 percent metallization). The EIF is a fixed position, sealed, three graphite electrode melting furnace that has been designed specifically for melting hot FASTMET DRI. The electrodes can be slipped with the power on while FASTMET DRI is charged and melted continuously. The EIF is stationary, has a fixed roof, and tapping is done by drilling out a tap hole similar to blast furnace tapping. Offgas from the EIF, primarily CO, is recycled to the FASTMET Process where it is used as fuel.

In the EIF, a major portion of the sulfur is removed during preparation of the heat. Silica contained in the gangue and coal ash can also be reduced, providing silicon level control in the FASTIRON. The carbon content can be varied by adjusting the carbon addition in the feed materials to the RHF. This provides for the desired carbon content in the liquid FASTIRON without the requirement to add carbon in the EIF. Alloys such as ferrosilicon or ferromanganese can be added to the EIF if desired. The FASTIRON product can be directly tapped into torpedo cars or ladles depending on the meltpoint specifics.

The idea of using an electric furnace to produce hot metal is not new. Electric furnaces have been producing hot metal and ferroalloys since the early 20th century. Submerged Arc Furnaces (SAFs) are known to be capable of smelting iron oxides and producing hot metal with 3.5 to 4.0 percent C. Typically, SAFs are choked with layers of oxides and carbon floating as a charge burden on top of the slag layer near the perimeter of the furnace. Heat for the process is generated by passing electric current through the slag from electrode to electrode.

The differences between FASTMET DRI and traditional SAF charge materials are substantial. It is reasonable to conclude that the typical SAF process cannot provide the most effective method of producing hot metal from FASTMET DRI. The FASTMELT melter (EIF) was therefore developed based on the properties of FASTMET DRI, a relatively high specific melting rate and the target analysis for the molten product. The operational concept for the EIF therefore incorporates features of the EAF, the SAF and those traditionally identified with the blast furnace. As noted above, this electric furnace has been aptly named the Electric Ironmaking Furnace (EIF).

**FASTMELT TESTWORK AT THE MIDREX TECHNICAL CENTER**

After completion of the installation of the EIF at the Midrex Technical Center, extensive testwork was done to confirm that process chemistries could be controlled. The objective was to prove that when using a combination of waste and oxide materials for feed, the carbon, silicon and sulfur levels in the hot metal could be controlled. The testwork was successful and Tables III and IV show mechanical design characteristics of the EIF and selected data from typical operations.

Some highlights from FASTMELT tests at the Midrex Technical Center are:

- Carburization of the molten iron to near theoretical saturation was easily achieved.
- Reduction of SiO₂ and MnO contained in the DRI occurred in the melter with subsequent pick-up of [Si] and [Mn] into the hot metal (similar to blast furnace thermochmistry).
- Iron yields were high as the slag typically contained less than 2 percent FeO during melting of DRI, often less than 1%.

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### RHF

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside Diameter</td>
<td>8.0 feet</td>
</tr>
<tr>
<td>Inside Diameter</td>
<td>3.5 feet</td>
</tr>
<tr>
<td>Active Hearth Width</td>
<td>9 inches</td>
</tr>
<tr>
<td>Feeding Rate of Greenballs/Briquettes</td>
<td>450 – 570 lbs/hr</td>
</tr>
<tr>
<td>Reaction Zones</td>
<td>3</td>
</tr>
</tbody>
</table>

### Electric Ironmaking Furnace (EIF)

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>250 KVA, single phase AC transformer</td>
</tr>
<tr>
<td>Electrode Diameter</td>
<td>3 inches</td>
</tr>
<tr>
<td>Production Rate</td>
<td>260 lbs/hr</td>
</tr>
<tr>
<td>Slag Adjustments</td>
<td>Sealed screw feeder/ hopper system</td>
</tr>
<tr>
<td>Roof</td>
<td>Water cooled</td>
</tr>
<tr>
<td>Sampling – Remotely Controlled</td>
<td>Hydraulically actuated probes and sealed sampling port for metal and slag</td>
</tr>
</tbody>
</table>

Table III  MDRC Technical Center RHF and EIF Mechanical Details

Table II provides a comparison of the characteristics of the SAF and EIF furnaces.

### Pulverized Coal (Reductant)

- Fixed Carbon: 71.1%
- Volatile Matter: 22.6%
- Ash: 6.3%
- Sulfur: 0.8%
- kcal/kg (Dry): 8,175

### Hot Metal Chemistry

- Carbon: 4.54%
- Silicon: 0.47%
- Manganese: 0.107%
- Sulfur: 0.013%
- Phosphorus: 0.036%
- Tap Temperature: 2650 – 2750°F

Table IV  Pilot Plant Data for Producing FASTIRON

- Sulfur contents of less than 0.03 percent were typical, with some as low as 0.005 percent obtained when processing the DRI made from briquetted iron bearing materials and ore pellet fines.
- Observed slag/hot metal sulfur partition ratios often reached values of 100 or more even with low basicity slags. These low hot metal sulfur levels increase the attractiveness of FASTIRON for use in the production of high quality steel.

### CONCLUSIONS

For treating steel mill wastes, FASTMET and FASTMELT Plants provide the following benefits:

- Recycling of iron-bearing wastes
- Elimination of need for on-site waste disposal
- Recovery of valuable iron units for steel production
- Recovery of zinc for sale
- Economical source of hot metal to supplement blast furnace production or EAF steelmaking
- Possible reduction of coke consumption
- Possible closure of sinter plants and coke ovens
- Low CO₂ emissions
By John T. Kopfle
Director-Marketing & Planning
Midrex Direct Reduction Corporation

Sorry, rock’n’roll fans, in this case we are referring to steelmaking charge materials. In addition to scrap, these include various forms of “alternative iron” such as direct reduced iron, hot briquetted iron, merchant pig iron and hot metal. In 1999, the percentage of alternative iron fed to electric arc furnaces in North America and worldwide was over 15 percent and 20 percent, respectively.

Why is this important? EAF steel production is the fastest growing route and now represents nearly 50 percent of total US production. Worldwide, over 250 million metric tons (Mt) of steel was made via the EAF in 1999. Growth in EAF production has been driven by the availability of scrap, reasonably priced electricity, process flexibility, low capital costs and EAF technology developments. The majority of future growth in world steel production will be via the EAF, whereas production from the blast furnace/basic oxygen furnace route will be flat or in decline. However, for the EAF to continue this growth, there must be sufficient high quality charge materials available at economical prices. DRI and HBI will play an important role because of their low residual content and their ability to cap scrap prices.

This year, world steel production has exploded, up 10 percent versus 1999. This increase has been possible due to the availability of domestic and imported scrap, DRI, HBI and pig iron.

As the use of alternative iron grows, more options will be available for the steelmaker. There are tremendous possibilities for improvements in DRI production and melting including the use of oxygen and high carbon DRI and HBI. Oxygen use has increased the productivity of MIDREX® Direct Reduction Plants by 50 percent or more since the early 1970s, thereby enhancing the economics of direct reduction. MIDREX Plants have now demonstrated the capability to produce DRI and HBI with carbon levels up to three percent, providing benefits in melt shop productivity and economics, as well as improvements in product quality.

Another exciting possibility is the Internet. Even steel, that “unglamorous, forgotten industry,” has jumped on the bandwagon. The future of steel-related e-commerce is far from certain, but it is clear that the Internet will become a powerful tool for disseminating information, reaching customers and reducing costs. Regarding the metallics market, the dissemination of information may be the most important result. The increased availability of pricing and sales volume information will expand the market and benefit the industry. There is now increasing discussion about establishing a futures market, facilitated by the Internet.

As the alternative iron market expands, there are increasing options for steelmakers. It is truly becoming a buyers’ market, a veritable cornucopia of options. Steelmakers now can select from a variety of choices regarding product type and temperature, method of procurement, contract length, pricing scheme, facility location, process type and financing. Technical assistance from producers and technology companies regarding the shipping, handling, storage and use of alternative iron is also available.

The decision to use alternative iron must be done with much consideration to properly assess all these factors. Unfortunately, some potential users attempt to shortcut the process and apply generic solutions. This temptation must be resisted, and the proper analysis must be done for the specific mill considering the use of alternative iron.

This all points to exciting times in our industry, and it is clear that “heavy metal” will play an important role.
From Dust to DRI: FASTMET® Waste Recycling at Kakogawa and Hirohata

By Hidetoshi Tanaka
Takeshi Sugiyama
Takao Harada
Hiroshi Sugitatsu
Masahiro Shimizu
Kobe Steel, Ltd.

INTRODUCTION
Kobe Steel, Ltd. and Midrex Direct Reduction Corporation have developed the FASTMET® Process for production of DRI from iron and steel mill waste. The viability of the FASTMET Process applied to steel dust/waste recycling has been verified, via testing at the Kakogawa Demonstration Plant (KDP) and at the first commercial FASTMET® Plant in Hirohata steel works of Nippon Steel Corporation, Japan. The KDP is now being converted to a commercial facility.

From both the economical and environmental points of view, the FASTMET Process has proven very attractive for waste recycling.

There are two major targets for waste recycling to the BOF or EAF. The first is high metallization of iron oxides that reduces the burden on the melting process. The second is high removal ratio of zinc that reduces the zinc concentration within the recycling loop. Kobe Steel has proven that the FASTMET Process achieves both high metallization and high zinc removal ratio in the waste recycling process through laboratory tests and tests at the Kakogawa Demonstration Plant. These tests resulted in the design concept of the FASTMET Plant at Hirohata.

KAKOGAWA DEMONSTRATION PLANT
Reduction tests were performed at KDP with an 8.5 m O.D. rotary hearth furnace (RHF). The RHF was heated with gas burners at 1,300° to 1,350°C. Pellets made of steel waste mixed with carbon were fed to the RHF and reduced in 12 minutes.

Product DRI (direct reduced iron) was discharged hot at approximately 1,000°C from the RHF into the sampling vessel. Pellets in the RHF were also sampled in each zone to evaluate the reduction curve. Residual carbon and the de-zinc curve were evaluated in the same manner. DRI compression strength and DRI temperature at the discharge were measured mainly to evaluate design data for a commercial plant, as these parameters are very important for DRI users.

TEST RESULTS
Table I shows an example of the chemical composition of the dry feed ball and the resulting DRI.

Metallization is calculated via the following formula:

\[ \text{Met(\%)} = \frac{\text{Met. Fe in DRI}}{\text{Total Fe in DRI}} \]

An average metallization of 90 percent (+1 mm DRI) was achieved through five sampling vessels.

Metallization and residual carbon curves examined through grabbed samples and discharged DRI are shown in Figure 1. Pellets rapidly heated in the RHF were reduced in a short time, with residual carbon decreasing as the pellets were reduced. The reduction reaction almost finished within 7.5 minutes as both the metallization curve and the residual carbon curve show.

The de-zinc curve is shown in Figure 2.

The de-zinc degree is calculated via the following formula:

\[ \text{De-zinc(\%)} = \frac{(1 - (\text{ZnO in DRI} / \text{Total Fe in DRI}))}{(\text{ZnO in dry ball} / \text{Total Fe in dry ball})} \]

According to the de-zinc curve, 99.0 percent de-zinc is achieved within 7.5 minutes. Samples including fines in the sampling vessels also show high de-zinc degree (average 92.0 percent).

The DRI compression strength (10 pieces) was measured as shown in Figure 3. An average 43.7 kg/p and 58.8 kg/p was obtained using Hirohata steel waste, which is high enough for hot transfer to the melt shop.

The discharged DRI temperature is shown in Table II. It is measured with a two color pyrometer at the discharge area.

<table>
<thead>
<tr>
<th>Dry Ball</th>
<th>Total Fe</th>
<th>Metallic Fe</th>
<th>FeO</th>
<th>C</th>
<th>S</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>58.70</td>
<td>17.10</td>
<td>36.60</td>
<td>11.90</td>
<td>0.17</td>
<td>0.75</td>
</tr>
<tr>
<td>DRI</td>
<td>82.20</td>
<td>74.20</td>
<td>7.40</td>
<td>3.30</td>
<td>0.23</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Table I  Chemical Composition of Dry Ball and DRI (%)

<table>
<thead>
<tr>
<th>Sample-1</th>
<th>Sample-2</th>
<th>Sample-3</th>
<th>Sample-4</th>
<th>Sample-5</th>
<th>Sample-4</th>
<th>Sample-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>970</td>
<td>985</td>
<td>1019</td>
<td>N.A.</td>
<td>N.A.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table II  DRI Temperature (°C)

<table>
<thead>
<tr>
<th>Zn</th>
<th>Pb</th>
<th>Cl</th>
<th>K</th>
<th>S</th>
<th>T.Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>44.70</td>
<td>4.50</td>
<td>3.79</td>
<td>5.85</td>
<td>1.86</td>
<td>1.20</td>
</tr>
</tbody>
</table>

Table III  Chemical Composition of Flue Gas Dust (%)
The chemical composition of the flue gas waste sampled from the flue gas is shown in Table III.

HIROHATA COMMERCIAL PLANT

The demonstration plant tests at Kakogawa proved that FASTMET can reduce the iron oxide contained in the steel waste at very high metallization, while removing zinc oxide. Hirohata was designed based on the laboratory tests and the Kakogawa Demonstration Plant test.

Hirohata was successfully constructed and started up 13 months from the effectuation of the plant supply contract. The major milestones of Hirohata are as follows:

- Mar. 1999: Effectiveness of Contract
- Oct. 1999: Started Erection Work
- Feb. 2000: Completed Erection Work
- Mar. 2000: Started Hot Commissioning
- Apr. 2000: Started Commercial Operation
- Aug. 2000: Verified Plant Performance

Hirohata started operation successfully as shown in the hourly waste treatment rate curve in Figure 4. The waste treatment rate has been increasing since commercial operation began in April 2000 and reached 23.7 t/h in August 2000, which amounted to 98 percent of the design waste treatment rate.

Figure 5 shows the plant availability during the continuous operation period. Plant availability has also been increasing and reached 94 percent in August.

The typical metallization degree at Hirohata is 91.9 percent and the de-zinc degree is 94.0 percent at a productivity of 100 kg-DRI/m²h, thus verifying the Kakogawa test results.

The flue gas waste contains very high zinc oxide content. Typically 63.4 percent Zn can be used as a resource for a zinc refinery. Zn content in flue gas waste is much higher than that of the Kakogawa test results, because the flue gas waste in the commercial plant is collected by a bag filter while the Kakogawa flue gas waste is sampled from flue gas directly.

In addition to the above benefits, Hirohata also showed that the FASTMET Process is environmentally friendly. The emissions limitations for all pollutants are satisfied, including dioxins. Typical emissions data are shown in Table IV.

KAKOGAWA COMMERCIAL PLANT

Kobe Steel will convert the FASTMET demonstration plant at Kakogawa into a commercial iron-bearing solid waste recycling facility as part of a plan to turn Kakogawa into a zero emissions facility by the end of 2001.

The demonstration plant will be modified to reclaim zinc-rich iron oxide dust from blast furnace and steelmaking operations, with a treatment capacity of 16,000 metric tons per year. The DRI unit will be upgraded to recover high zinc content dust. The facility will use waste oil as the primary fuel source. It is anticipated to go into operation in spring 2001.

The high iron content DRI will be used in steelmaking operations. Plans call for zinc recovered from the offgas to be sold.

CONCLUSIONS

Following good laboratory test results, reduction tests at the Kakogawa Demonstration Plant were performed and high metallization and high de-zincification were achieved when processing steel mill wastes. Based on the results achieved at Kakogawa, the first commercial plant was built at Hirohata for steel waste recycling. Hirohata was successfully constructed and started up in 13 months from contract. The plant performance of Hirohata has met expectations and is better than Kakogawa test results.

The high quality of both DRI and by-product at Hirohata is reflected in the product DRI metallization and de-zinc content. The hot DRI sensible energy is utilized in the melting furnace to the maximum extent in Hirohata. The Kakogawa Plant is being converted for continuous operation and will be the second commercial facility. The FASTMET Process is commercially proven to be very suitable for waste recycling from both economical and environmental aspects.
Midrex News & Views

2000 Midrex Operations Seminar

From October 8 – 12, 2000, Midrex hosted its annual Operations Seminar held in Charlotte, North Carolina, drawing 22 operators from 13 MIDREX Plants worldwide. Shown above, this year’s attendees, including MIDREX Licensees, Midrex engineers, executive staff and members of PSI, take a break before lunch and returning to the afternoon’s session.

Ed. Note: For more information regarding the Operations Seminar and other technical support see Tony Elliot’s commentary “Supporting Our Plants: Midrex Technical Services” on page 2.

Midrex Wins Marketing Award

The Carolinas’ chapter of the Business Marketing Association awarded Midrex Direct Reduction Corporation a 2000 ProAd Award for its new corporate brochure at the 20th annual ProAd competition recently held to honor marketers throughout the Carolinas. Midrex's new corporate literature piece, designed with Adgroup of Charlotte, North Carolina, took a silver for outstanding corporate capabilities brochure.

2000 Midrex Operations Seminar

PSI Creates Agreement to Supply Complete Set of Reformer Tubes and Buy Used Tubes

Professional Services International (PSI), of Charlotte, North Carolina, has concluded an agreement with Steel Industry Services Corp., the offshore purchasing arm of Acindar, to supply a complete set of reformer tubes and reformer catalyst for the plant in Villa Constitucion, Argentina. PSI will purchase the used tubes from Acindar when they are removed from the reformer in mid-2001. Midrex will provide technical assistance to PSI and will also be involved in the quality assurance program.

For more than a decade PSI, a global supplier of equipment and material needs, has been obtaining the equipment, spare parts and operating materials required for MIDREX Plants and other industrial facilities for operations, maintenance shutdowns, modifications or expansions.

Hadeed Training Seminar

In early October, Midrex hosted a custom licensee process-training seminar for four plant operators from the Hadeed plant located in Al-Jubail, Saudi Arabia. Held at Midrex's corporate offices in Charlotte, North Carolina, the weeklong specialized process training addressed some of the latest trends and technology for MIDREX Plant operations. Topics included: new technologies, improved plant operations, methods for improved efficiency, plant safety, trouble-shooting and SuperData program training. This specialized process training, in addition to the Operations Seminar and general Technical Services support, provides MIDREX Plant operators with invaluable instruction and assistance.
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